Analysis of Telecooperation in the German Automotive Industry

Ludger Schmidt, Jörg Depolt, and Holger Luczak

Institute of Industrial Engineering and Ergonomics, RWTH Aachen University, Germany.

Abstract. In times of increasing globalization and high customer demands, product development in the automotive industry is becoming more and more decentralized. Consequently, cooperation between enterprises must be enhanced and deepened. This cannot be handled by conventional telecommunication technology alone. An increase in work efficiency and productivity can be reached by telecooperation, i.e. computer-supported teamwork. This paper compares conventional cooperation processes and telecooperation in the framework of an extended efficiency analysis. It could be shown that telecooperation reduces both costs and time of cooperation processes and enhances the subjectively-felt quality of information and work results.

Keywords. Telecooperation, Extended efficiency analysis, Collaborative engineering design.

1. Introduction

The number and intensity of cooperation processes in product development in the automotive industry have steadily grown in the past (e.g. Luczak et al., 1997; Depolt and Uehlenbruck, 1998). By restructuring their relationships with suppliers towards long-term, trustful business relations, makers share the risk of product development by creating development cooperations. Consequently, product engineering designers are required to work cooperatively.

Likewise, the number of external product development departments has increased in recent years. As a consequence, the relationship between car makers and suppliers has changed: from an asymmetric, hierarchical system towards a more equivalent relationship of mutual dependency (Wognum, Fisscher and Weenink, 2002). Telecooperation offers great potential in allowing to integrate external product design engineers efficiently. For example, car maker BMW and its supplier Benteler AG, working in the field of car carrier systems and metal forming, implemented a UNIX-based system for CAD teleconferencing in order to develop a rear axle system for a passenger car. It could be shown that both process durations and consequential costs of communication were significantly lower than before, underlining the efficiency of telecooperation (Luczak and Eversheim, 1999).

A efficiency analysis exclusively focusing on monetary criteria omits non-monetary aspects like product quality and system usability, though. Therefore, an extended concept of efficiency is applied here, which analyses the communication and collaboration between car maker and supplier and the influence of telecooperation. A preliminary task and cooperation analysis (Luczak, 1997), specifically tailored to the telecooperation environment, is necessary in order to come to transparent and valid conclusions concerning efficiency. An integrated approach for such an extended efficiency analysis is lacking. The approach utilized in this study is described in the next paragraph.

2. Extended Efficiency Analysis

Four aspects must be considered in developing a multi-dimensional approach for the evaluation of telecooperation:

- utilizing models to continuously analyze communication and cooperation in a pre-post-design,
- selecting target dimensions for monetary evaluation aspects,
- operationalizing non-monetary target dimensions based on key figures, and
- taking into consideration a possibly unreliable data basis.

This approach can be arranged in three phases (see Figure 1).

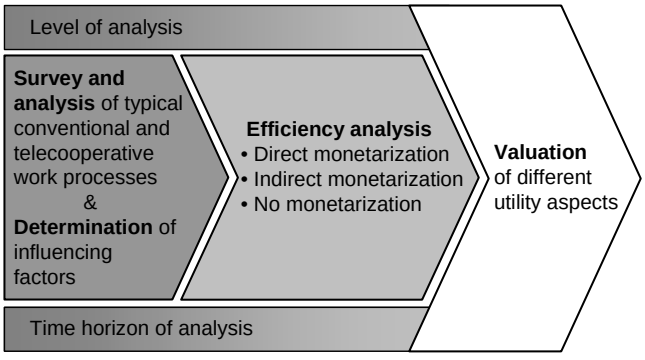

Figure 1. 3-phase-concept of an extended efficiency analysis

2.1. Phase 1: Survey and analysis of typical conventional and telecooperative work processes

Conventional and telecooperative work processes are collected by a communication and cooperation analysis. In the study presented here the communication analysis was based on a questionnaire, focusing on a subjective needs analysis concerning information technology as well as the identification of

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE	2. REPORT TYPE	3. DATES COVERED
00 JUN 2004	**N/A**	**-**

4. TITLE AND SUBTITLE	5a. CONTRACT NUMBER
Analysis of Telecooperation in the German Automotive Industry	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Institute of Industrial Engineering and Ergonomics, RWTH Aachen University, Germany**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S)
	11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release, distribution unlimited

13. SUPPLEMENTARY NOTES
See also ADM001766, Work with Computing Systems 2004 (Proceedings of the 7th International Conference).

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			
unclassified	**unclassified**	**unclassified**	**UU**	**5**	

weak spots. The questionnaire used in the study contained six content partitions: field of activity, communication infrastructure, information management, communication behavior, communication failures and advantages/disadvantages of utilized communication tools.

The method utilized for cooperation analysis (Killich et al., 1999) was based on three concepts:

- a modified version of Harel's statecharts to represent poorly defined processes (Harel, 1988),
- a modified subset of Oberquelle's Role-Function-Activity Nets (RFA nets) to represent cooperation partners, information flow, and cooperation relationships (Oberquelle, 1987), and
- the structure building technique (Groeben and Scheele, 1984) with predefined elements.

The modified subset of Oberquelle's RFA net, the RA net, represents cooperation relationships between roles by so-called cooperation elements (based on previous job analysis methods), which are:

- informing (e.g. sending or receiving information without feedback),
- information exchange and feedback (e.g. sending information, receiving a feedback),
- coordinating procedures and/or decision making (e.g. defining a schedule),
- problem solving (e.g. discussing conflicting design parameters).

Furthermore, two elements were added (cf. McCormick et al., 1989):

- signalizing and
- assigning.

2.2. Phase 1: Determination of influencing factors

100 employees who were familiar with telecooperation filled out a questionnaire concerning advantages and disadvantages of this technology. A factor analysis produced four target dimensions for evaluation: Costs, time, quality and hygiene factors.

2.2.1. Costs

Figure 2 shows the crucial factors for calculating the costs (both initial and running costs).

2.2.2. Time

In order to evaluate this dimension, the following aspects were taken into consideration:

- time changes because of cooperation processes,
- prolongation factor (comparing two specific activities),
- reaction capability, and
- reaction speed.

The prolongation factor refers to the degree to which an activity is prolonged or accelerated by using telecooperation.

	Preparation - Conference - Trip	Outward trip	Con-ference	Return trip	Wrap-up
Connection costs			X		
Personnel costs	X	X	X	X	X
Hotel costs			X		
Expenses		X	X	X	
Travel costs		X		X	
Coordi-nation costs	X				(X)
Clearing costs					X
Important factors	Duration, number of participants	Means of travel, distance	Duration	Means of travel, distance	Result, number of participants

Figure 2. Overview of cost factors (grey cells = only conventional conference, cells with grey stripes = only telecooperation, white cells = both)

2.2.3. Quality

Four factors refer to the quality of telecooperation:

- quality of information (e.g. actuality, consistency, unambiguousness),
- quality of process (e.g. adequate media usage),
- quality of work environment (e.g. reduction of stress, increase of competence), and
- quality of work result (e.g. fewer call backs).

All factors were rated on a seven-step scale within the framework of the pre-post-design.

2.2.4. Hygiene factors

Hygiene factors that are not fulfilled lead to undesired consequences and thus are knock-out criteria. The following hygiene factors were utilized:

- system ergonomics,
- compatibility,
- stability,
- security, and
- technical infrastructure.

2.3. Phase 2: Efficiency analysis and level of monetarization

The second step in the 3-phase-concept of the extended efficiency analysis implies the refinement of valuation criteria based on boundary conditions. In order to represent person-oriented work processes, work place and team level were chosen as level of analysis, i.e. more aggregated levels of analysis (business company, national economy) were excluded. Data were collected continuously, i.e. time horizon was not limited to single data. Conclusions based on continuous data are more

valid than those based on single observations which represent only a small process section.

The level of monetarization refers to a classification approach that differentiates monetary, indirectly monetary and non-monetary criteria. An unequivocal mapping of the target dimensions is not possible, though; a methodical transformation process from the lowest level of monetarization to the highest (direct monetarization) is not mentioned in the literature, i.e. level of monetarization is rather a theoretical dimension. Yet, it is plausible to map costs as direct monetarization, time as indirect monetarization and quality as no monetarization. Figure 3 visualizes the basic structure of the described multidimensional approach.

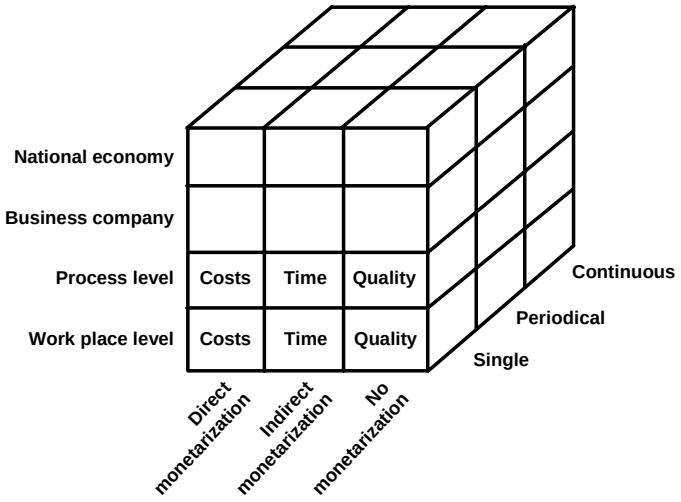

Figure 3. Basic structure of multi-dimensional efficiency analysis for telecooperation

2.4. Phase 3: Valuation of different utility aspects

The third phase includes the valuation of the different utility criteria mentioned in phase 2. Dependent on the target market segment and the strategic position of the business company, costs, time and quality will be valued in a different way.

3. Empirical Investigation

An empirical case study was conducted in combination with a vehicle project. 39 employees were investigated over a time period of 29 months. In sum, the employees visited 156 component suppliers, and all in all 720 trips were made.

The average distance of the German component suppliers in the current project was about 300 km. It must be mentioned that component suppliers get very rare with distances larger than 600 km (see Figure 4). This could indicate that many German component suppliers still have close cooperations with their business partners.

The investigation featured a representative component supplier who had both cooperations with or without telecooperation. He is located at a distance of 325 km from the manufacturer and mostly works as an engineering design service provider. This was shown by calculating a key figure consisting of distance, intensity of cooperation, kind of cooperation scenario and financial reserves which are directly linked to the requested product. For example, in the realm of research and development, these are the correlating research and development volume.

In order to depict the costs, a sensitivity analysis was conducted. Thus, the effect of distance on costs can be visualized (in order to simplify things, the cost function is depicted in a linear way).

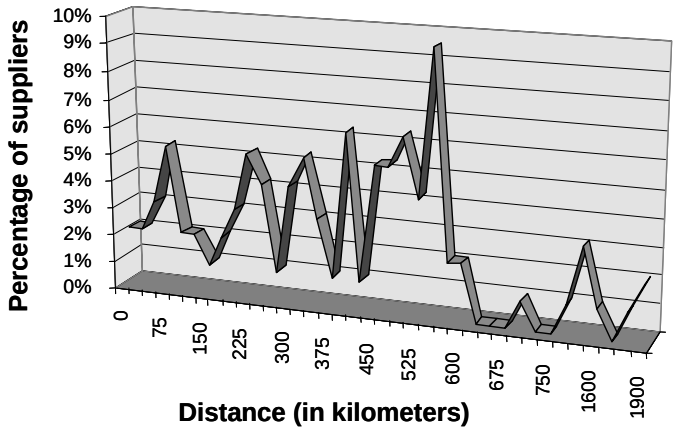

Figure 4. Geographical distribution of suppliers

4. Results

4.1. Efficiency analysis of conventional and telecooperative conferences regarding costs

The following pictures show the cost difference $\Delta(C_{conventional} - C_{telecooperative})$ for a meeting of two (left hand in Figure 5) and four (right hand in Figure 5) participants. This cost difference depends on the duration of the meeting and the distance of the cooperation partners. It is assumed here that the shortest meeting duration is five minutes. Further, it is assumed that the cooperating partners remain in the same places. Triple conferences are neglected. It is assumed that the telecooperative conferences' durations are equivalent to the presence on site. Different from telecooperative conferences, having a contact person on site often results in discussing additional topics.

Figure 5 shows the progression of the cost difference when a business trip is fully replaced by a telecooperation session, including the same people and the same duration. Only one participating person traveled in the conventional conference condition, i.e. in the teleconference condition, only one person was substituted. The maximum time for preprocessing and wrap-up was 45 minutes. It must be taken into consideration that this time proportionally grows with shorter conferences. This was taken into account.

Based on ca. 2500 sampling points, the results show a high degree of dependence on the distance from the cooperation partner. The kink in the plain that is parallel with the conference time axis represents the "one-day-trip"-boundary. Perpendicular to that is another kink, which can be explained by the transgression from using a department vehicle to using a car pool vehicle. In short, substitution entails positive cost differences, which increase with the number of participants.

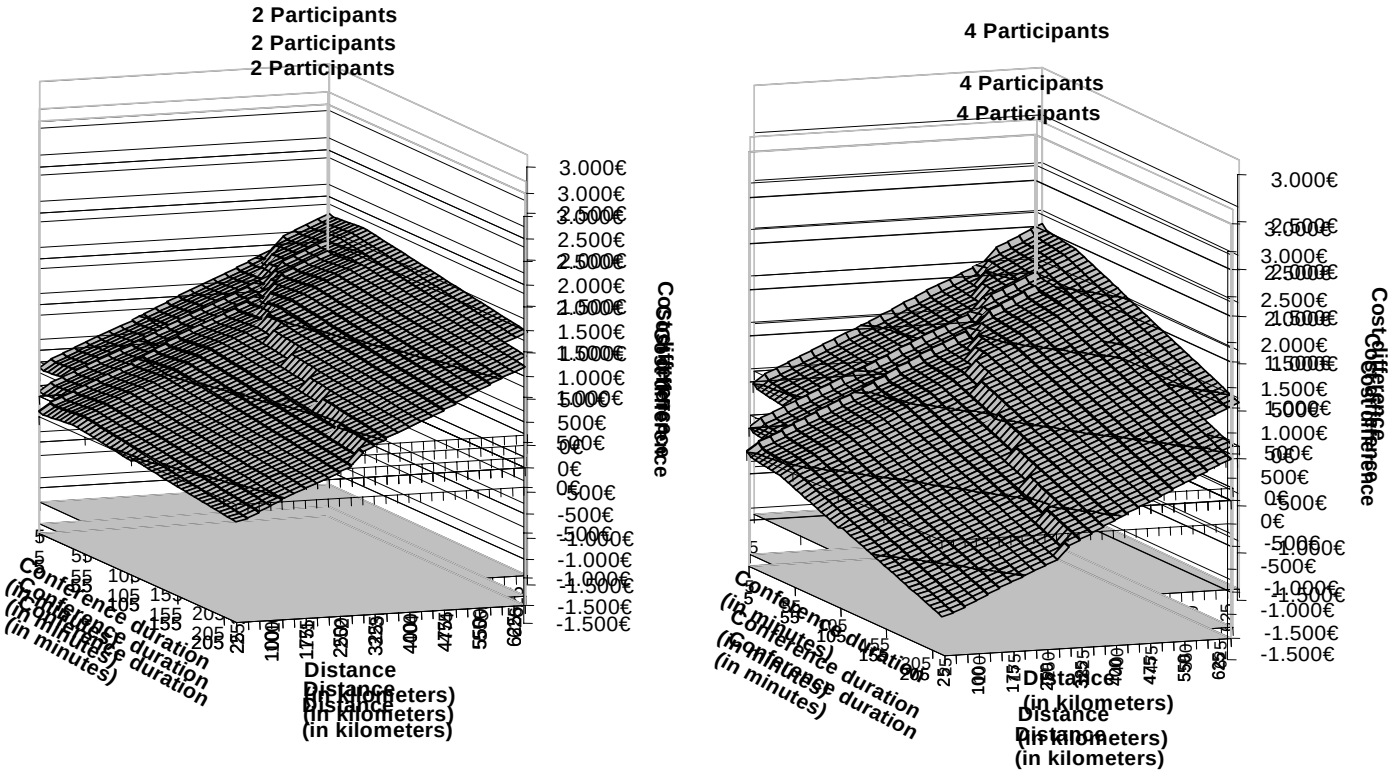

Figure 5. Progression of cost difference with regard to the substitution of one person traveling by a telecooperation session

The impact of conference duration grows with the number of participants. According to experiences during data sampling, the time for preprocessing and wrap-up of telecooperation meetings including numerous persons was adjusted. Calculations show negative cost differences in case of long conference times and small distances (and vice versa). The slant of the plain depends on the number of participants. In contrast, the cost difference for a short meeting over a large distance is practically independent of the number of participants.

4.2. Analysis of collaborative engineering design regarding time and quality

The complexity of a person-oriented work process is equated here with the complexity of the product that is to be developed. Further, key figures were construed on the basis of the task analysis:

- conference duration,
- number of employees,
- number of adjacent components,
- number of described problems,
- access to color information and snap shots, and
- access to electronic and physical documents.

Key figures showed that referred to comparable cooperation relationships (see paragraph 2.1), teleconferences took 15 % more time on average than conventional conferences. The prolongation factor takes this into consideration. Still, cooperation process was 30 % shorter if compared to asynchronous cooperation (fax, telephone calls). Quality of information, quality of work process and quality of work results were rated at least one tick higher if compared to conventional conferencing.

5. Summary

It could be shown that telecooperation leads to efficiency effects both in conferencing and in product development. In addition to monetary aspects, the pre-post-design also showed positive effects with respect to the factors time and quality. If cooperation processes are seldom or very complex, only marginal monetary improvements resulted. Since in the realm of production, the potential for rationalization has been exhausted, telecooperation offers the possibility to shorten product development processes significantly, at the same time reducing costs and enhancing the quality of work processes of the involved persons.

6. References

Depolt, J., & Uehlenbruck, G. (1998). Erweiterte Wirtschaftlichkeitsberechnung von Telekooperation in der Automobilhersteller/Zulieferer-Beziehung. *VDI Berichte 1435: Prozessketten für die virtuelle Produktentwicklung in verteilter Umgebung* (pp. 339-360). Düsseldorf: VDI.

Groeben, N., & Scheele, B. (1984). *Heidelberger Strukturlegetechnik*. Weinheim: Beltz.

Harel, D. (1988). On Visual Formalisms. *Communications of the ACM, 31 (5),* 514-530.

Killich, S., Luczak, H., Schlick, C., Weissenbach, M., Wiedenmaier, S., & Ziegler, J. (1999). Task modelling for cooperative work. *Behavior and Information Technology 18 (5),* 325-338.

Luczak, H. & Eversheim, W. (1999). *Telekooperation – Industrielle Anwendungen in der Produktentwicklung.* Berlin: Springer.

Luczak, H. (1997). Task Analysis. In G. Salvendy, G. (Ed.), *Handbook of Human Factors and Ergonomics (2nd Edition)* (pp. 340-416). New York: Wiley.

Luczak, H., Stahl, J., Schlick, C., Depolt, J., & Springer, J. (1997). Tele-cooperation for locally distributed product development. In H.M. Khalid (Ed.), *Proceedings of the 5th Southeast Asian Ergonomics Society Conference on Human Factors Vision – Care for the Future* (pp. 67-74). Kuala Lumpur: IEA Press.

McCormick, E. J., Mecham, R. C., & Jeanneret, P. R. (1989). *Technical Manual for the Position Analysis Questionnaire (PAQ; 2nd ed.)*. Logan, UT: PAQ Services. Palo Alto, CA: Consulting Psychologists Press Inc.

Oberquelle, H. (1987). *Sprachkonzepte für benutzergerechte Systeme*. Berlin: Springer.

Wognum, P.M., Fisscher, O.A.M. & Weenink, S.A.J. (2002). Balanced relationships: management of client-supplier relationships in product development. *Technovation, 22*, 341-351.